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USING IMMERSIVE VIRTUAL REALITY FOR ELECTRICAL SUBSTATION TRAINING

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ABSTRACT

Usually, distribution electricians are called upon to solve technical problems found in electrical substations. In this project, we apply problem-based learning to a training program for electricians, with the help of a virtual reality environment that simulates a real substation. Using this virtual substation, users may safely practice maneuvers with varying degrees of complexity. To improve the user's sense of immersion, interactive devices such as the Oculus Rift virtual reality headset are going to be adopted. The project's stakeholders had a good impression of the device and believe that the proposed methodology will improve the training and effect positively the electricians' performance, reducing accidents inside the substation area and decreasing the time required to reestablish the power supply after a failure.

KEYWORDS

Electrical Simulation, Immersive Virtual Reality, Interactive Devices, Problem-Based Learning, Training Staff.

1. INTRODUCTION

The electric power system consists of power generation, transmission and distribution networks, and load consumption. The power generation is the origin of the electrical energy. A transmission network is composed by high-voltage power lines, which drive electric power from a generation station to a load center area, as they are usually far apart for long distances. A distribution system has medium and low voltage networks and conducts electrical energy from the transmission system to industrial, commercial and residential loads. These sections of the electric power system are linked by electric substations. Their function is to reduce or increase voltage levels in order to supply correctly each section of the system, thereby establishing a connection between the power generation and the transmission system on the one hand, and the transmission and distribution systems on the other (Massachusetts Institute of Technology, 2011).

A substation has the electrical and protection equipment necessary to transform power with safety and efficiency and offer an adequate power quality to the customers of the distribution system. A substation comprises transformers, regulators, circuit breakers, disconnectors, monitoring equipment, protection relays, electrical buses, and others (Blume, 2007). Since this facility is a fundamental section of the electrical system, it is very important to maintain its proper operation. Thus, if there is a problem in the substation after an electrical fault in its area, the site must be repaired as soon as possible. As a result, the customers would not have their energy supply interrupted for a long period and damages to the power grid or equipment of customers could be avoided. Electricians allowed to work in substations are the professionals who will respond in most events of technical problems in distribution substations in a local electric utility.

In order to obtain the best performance of the electricians, electric companies must offer an efficient training to guide them properly. Therefore, the project in this paper proposes an improvement of electricians' training program by including a problem-based learning methodology within an application of virtual reality (VR) in the current training program of the utility. A virtual substation, as much realistic as possible, with all its equipment has been developed to give electricians the opportunity to safely operate the equipment and execute basic and emergence maneuvers.

2. RELATED WORK

2.1 Immersive Virtual Reality in Education and Training

Adopting a VR environment for education and training can be very attractive for several reasons. First, as it does not involve security risks that may exist in the real world, users can freely explore the environment without harming themselves, their colleagues or even damaging the environment. Second, users can try to perform tasks and solve the proposed problems how many times they require, without the pressure of a classroom full of colleagues (Patel et al, 2006) or even a formal evaluation. Thus, this kind of environment encourages the user to conduct his/her learning at his/her own pace, with no risks (Mikropoulos et al, 1997). Given these characteristics, VR environments have been developed for different trainings (Grabowski and Jankowski, 2015; Sacks et al, 2013; Ausburn and Ausburn, 2004).

A VR environment is not only capable of representing and simulating real or fictional environments, but also making users feel like they are physically present in those places (Ausburn and Ausburn, 2004). In order to be more effective and let the users focus only on the tasks that must be performed, the VR environment must be immersive. Usually, immersion can be achieved by covering the whole field of vision of the user with a Head Mounted Display (HMD).

2.2 Electrical Simulators

Electrical simulators are useful to help professionals to understand ordinary and emergence operations that he/she will face in a work daily basis. One example of electrical simulator is STOP (Silva, 2011). In STOP, users interact with single-line diagrams of electrical systems, simulating faults in the systems and setting relays, circuit breakers, transformers and other equipment. However, as the only way to interact with the systems is through the diagrams, users do not have a realistic experience of manipulating the equipment.

Other simulators offer a more realistic experience, such as Virtual Substation and Furnas 02 (Silva, 2012). Both simulators aims to train new technicians to control and/or operate an electrical substation or a power plant, so that the facilities were modeled in 3D in order to look like a real substation and power plant. In fact, it is possible to interact with most of the equipment through joysticks and VR glasses, but the look and feel of these simulators is not as realistic as the project presented in this paper demands.

It is not common to find substation simulators that use immersive VR to give the users a good impression of how a real substation is and, more important, how to operate the real equipment in a maintenance or emergency maneuver. A virtual electric substation does not replace a real one, although it is a valuable resource for training purposes, as a real substation may not be available for trainings. Even if it is available, several actions that are commonly performed in electric substations involves risks to the electricians, who may suffer injuries if performing unsecured maneuvers or lacking personal protective equipment, and to customers, who may face a blackout if a maneuver is wrongly done by the electricians.

3. MATERIALS AND METHODS

Nowadays, the training program of the electrical utility consists of theoretical and practical lessons. However, these practical lessons allow electricians to have only a very restricted contact with real substations so that it is nearly impossible to practice maneuvers during the training program. Therefore, a virtual substation designed as a VR environment will be a valuable tool to complement and improve the training program. Besides that, as the emergency calls in the electrical substation do not occur very often, the virtual substation will allow electricians to periodically practice and keep their skills sharp and proficient.

To deliver the required realism, a real substation should be represented in the VR environment, containing accurate 3D models of all equipment and simulating the exact behavior of them. Moreover, as immersion is a must-have, HMD support is also required. To fulfill these requirements, the Unreal Engine (Epic Games, 2015) was chosen, as it can render high quality graphics, is compatible with HMD and has a very active and supportive community. In addition, the selected HMD for this project was Oculus Rift (Oculus, 2015), as it is one of the most promising technologies available at the time that this paper was written, with a reasonable

support and rich online documentation. As the HMD covers the user's field of vision, using a keyboard and a mouse could be a bit clumsy. Gesture-based user interfaces could provide a more natural interaction with the VR environment and are still under analysis by the authors.

The behavior of the virtual substation was modeled by discrete event simulation, as its operations can be represented as a defined sequence of processes. Then, this virtual substation can be seen as a learning environment where instructors will select a specific issue that is avoiding the substation to work properly whereas students will have to investigate and isolate or solve that problem to fix the substation. In other words, students can learn by themselves in the environment while practicing to solve problems that may occur on real substations, as the Problem-Based Learning pedagogy recommends (Hmelo-Silver, 2004). This kind of methodology is characterized as an active learning, which was chosen because it is more attractive and effective for experienced professionals (Bonwell and Eison, 1991).

To evaluate the performance of the student while restoring the substation, some criteria will be considered: proper usage of the personal protective equipment, completed tasks, correct interaction with the equipment to find the problem and a solution. Additionally, this assessment will be presented to instructors and students as a final score, similar to video games, enhancing the experience of the users and their motivations.

4. PRELIMINARY RESULTS

Although this is a work in progress project, it does have a few valuable results. At the time that this paper was written, about half of the 3D models of the equipment were designed and integrated into the VR environment. Figure 1 shows some of the models already included in the VR environment.

Figure 1. 3D models for low voltage circuit breaker and disconnector (left) and details of an existing panel (right)

To validate the behavior of the substation and the discrete event simulation, an emergency maneuver was implemented in the VR environment. In this emergency maneuver, part of the substation was turned off due to a short circuit, which means that customers were facing a blackout. Then, an electrician in the substation should identify the root cause of the short circuit, isolate it, and try to turn the substation on again – and all of these tasks should be performed by interacting with the substation's equipment. To manipulate the equipment, the user can work with the Oculus Rift and a joystick or an ordinary monitor, keyboard and mouse.

An informal evaluation of the VR environment and the emergency maneuver selected was done with technicians and instructors from the local electric utility. As there were some 3D placeholders in the environment instead of models of the real equipment, some stakeholders were not able to envision the substation correctly, indicating that the placeholders are not easy to understand. Therefore, the design of the 3D models was re-prioritized and became a high priority task for the development and graphics teams. Despite this issue, the stakeholders were able to point a few pros of using the proposed VR environment:

- Improved electrician qualification, resulting on improved performance when some maneuvers are required in a substation;
- Reduced time to re-establish energy after a blackout, given that electricians will be able to successfully conclude more emergency maneuvers in a shorter time than nowadays;
- Reduced accident rate in substations, as electricians will be able to practice good safety practices when performing the maneuvers in the VR environment.

The pros indicate the potential of this project to benefit both the electricians and the society as a whole since the substation issues that cause blackout may be quickly repaired due to a better qualification.

5. CONCLUSION

This paper presented the project of a virtual substation being developed as an immersive VR environment, which offers a safe training area and represents accurately the behavior and operation of the system modeled. The proposed environment should at least partially suppress the current lack of practice of electricians in real substations, enabling them to explore the virtual substation and practice basic and emergency maneuvers, applying all concepts learned in theory classes with safety and without external pressure. An improvement on the electricians' performance is also expected, in the form of reduced accident rates and shorter time to re-establish the energy supply.

In the informal evaluation with the stakeholders, it was noticed that they expected a 3D scenario designed before the beginning of the maneuvers' simulation, exposing that having a realistic environment can call more attention than a simulation case without external features. Nevertheless, they were positive with the project's progress and with the immersive sense given by the use of the Oculus Rift. Other interactive devices (for instance, those with motion detection) are under analysis to improve the experience in the VR environment.

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